COMBINED DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled ROD REPLENISHMENT SYSTEM FOR USE WITH SINGLE CRYSTAL SILICON PRODUCTION, the specification of which

☒ is attached hereto.

☐ was filed on _____ as United States Application No. _____.

☐ was described and claimed in PCT International Application No. _____, filed on _____, and as amended under PCT Article 19 on _____ (if applicable).

☐ and was amended on _____ (if applicable).

☐ with amendments through _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56. If this is a continuation-in-part application filed under the conditions specified in 35 U.S.C. § 120 which discloses and claims subject matter in addition to that disclosed in the prior copending application, I further acknowledge the duty to disclose material information as defined in 37 C.F.R. § 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) of any foreign application(s) for patent or inventor's certificate or of any PCT International application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT International application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) on which priority is claimed:

Prior Foreign Application(s)

			Priority Claimed?	
			☐	☐
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No

I hereby claim the benefit under Title 35, United States Code,§ 119(e) of any United States provisional application(s) listed below:

Application Number	Filing Date
60/244,774	October 31, 2000

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) or § 365(c) of any PCT International application(s) designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT International filing date of this application:

Application No.	Filing Date	Status: patented, pending, abandoned

I hereby appoint the practitioners associated with the customer number provided below to prosecute this application, to file a corresponding international application, and to transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under § 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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In one specific example, generally according the to the process shown in FIGS. 10A-10F, 100 kg of polycrystalline chunk is loaded into a 24 inch crucible. Two polycrystalline silicon rods, each 120 mm in diameter by 900 mm in length, are attached to an RRM via keyhole attachments generally as shown in FIG. 4A. The rods each weigh 23.7 kg, for a total replenishment charge of 47.4 kg. By melting of the polycrystalline silicon rods, the molten silicon in the crucible is increased from 100 kg to 147.4 kg, a 47% increase in the amount of silicon available for converting into single crystal silicon ingot.

By using a RRM it is possible to reduce the number of times an isolation valve needs to be opened and closed, to more completely use polycrystalline silicon rods, and to reduce the total operating time.

It will be apparent that many changes may be made in the above-described embodiments. For example, although it is most common for charge replenishment rods to be made of polycrystalline silicon, such rods could be made of single crystal silicon. Thus single crystal silicon ingots that prove not to be suitable for wafer production could be machined and used as charge replenishment rods. And it will be appreciated that the bottom of an upwardly opening groove need not be perfectly flat. More importantly, the groove should be sufficiently deep that as the rod is melted from the bottom, the top of the rod separates into two or more pieces that fall into the melt. Also, although most of the illustrated embodiments show rods having top and bottom surfaces that are generally planar and that are generally perpendicular to the rod axis A_1, other embodiments could have other arrangements. For example, the top surface can extend at an angle to the axis A_1, such that the perimeter top surface is distinctly elliptical in general appearance as viewed perpendicularly to the surface. And if that angle is large enough, one end of the groove can be at the intersection of the groove with the top surface of the rod, instead of at the side surface of the rod. In such arrangements, if the

In addition to the shapes shown in FIGS. 3A and 3C, other shapes can be used for the keyhole system such as a keyhole having a body portion of generally square or rectangular cross-section. The basic concept is to allow the connecting of the rod hanger 152 to the polycrystalline rod 134 such that the rod can be centered on a rod hanger 152. The keyhole 150 is fabricated such that at least the neck portion provides a slot or hole that traverses a polycrystalline silicon rod 134 between two locations on the surface of the rod to provide an open space that extends between those locations and to the top of the rod, which allows the two sections 158 of the polycrystalline rod 134 to separate from the rod hanger 152 upon melting of the rod up to the lowest open horizontal pathway provided by the groove which divides the top portion of the rod. In addition, the body portion 166 of the keyhole 150 should be larger in dimensions than the body portion 170 of the rod hanger 152 so that a gap is provided therebetween, except for a small area at the top where the surface which defines the body portion 166 engages the surface of the body portion 170.

FIGS. 4A and 4B show a RRM that is capable of holding two rods. In FIGS. 4A and 4B, elements that are similar to those shown in FIGS 3A and 3B bear the same element numbers, but in those cases the numbers in FIGS. 4A and 4B are incremented by 100. In this system, the support body 260 has four legs, two outer legs 274 and two inner legs 275. The seed holder 276 is positioned between the two inner legs 275. And one rod holder 252 is positioned between each outer leg 274 and the nearest inner leg 275. The seed holder 276 and both of the rod holders 252 are keyed to the shaft 280, so that the seed holder 276 and rod holders 252 all pivot with the shaft about the axis A_2.

When silicon rods are connected to the rod holders 252, the pivoted member will be positioned as shown in FIG. 4A with the rod holders 252 extending downwardly and seed holder 276 extending upwardly. The illustrated pivoted member has a center of

connected together to provide a pivoted member. A pivot system is provided to allow the pivoted member to pivot about a generally horizontal pivot axis A_2. In the illustrated system, the pivot system includes a shaft 180 that is supported by the support body 160. The shaft 180 supports the seed holder 176 in such a manner that the seed holder can pivot relative to the support member 160. In particular, the seed holder 176 is secured to the shaft 180 so that the seed holder pivots with the shaft. And the shaft 180 extends through openings through the legs174 of the support member 160 so that the shaft can pivot relative to the support member 160. Preferably the shaft is supported within low friction bearings, such as Teflon® coatings on the surfaces that define the openings that receive the shaft.

The rod holder 152 is rigidly attached to the seed holder 176 so that the seed 178 is maintained in a fixed position relative to the rod holder 152. The seed 178 extends in a direction away from the pivot axis A_2, and the rod holder 152 extends in the opposite direction away from the pivot axis. The free end 179 of the seed 178 and the rod holder 152 lie in a plane that includes the pivot axis A_2. This positioning could be accomplished in ways other than securing the rod holder 152 to the seed holder 176. For example, the rod holder could be fixedly secured directly to the shaft (not shown). And, although the illustrated construction is advantageous for balance purposes, it would be possible to design a system wherein the free end 179 of the seed 178 and the rod holder 152 would not both lie in a plane that includes the pivot axis A_2.

When a polycrystalline silicon rod is connected to the rod holder 152, the pivoted member will be positioned as shown in FIG. 3A with the rod holder 152 extending downwardly and seed holder 176 extending upwardly. The illustrated pivoted member has a center of gravity located such that, once the load is removed by melting of the polycrystalline silicon rod, the pivoted member inverts, to the position shown in FIG. 3B, wherein the rod holder 152 extends upwardly and seed holder 176 extends

Detailed Description

A typical CZ puller 10, as shown in FIGS. 1A and 1B, has two parts, an upper chamber 12 and a lower furnace chamber 14. These two chambers are separated by an isolation valve 16. The puller 10 has a lift mechanism that includes a cable or shaft pulley system 18 in the upper chamber 12. The pulley system 18 is connected to a cable or shaft 20 that is used for raising or lowering silicon inside the puller 10. At the end of the cable or shaft is a seed holder 22, which can be used either to attach a CR rod to the cable or shaft, or to hold a single crystal silicon seed.

The lower furnace chamber 14, which can be isolated from the upper chamber 12 by the isolation valve 16, contains a heater 24 used to melt polycrystalline silicon chunks 26 inside a quartz crucible 28. The quartz crucible 28 can be raised or lowered within the heater by a succeptor 30. Depending on the type of single crystal silicon that is being grown, a heat shield 32 may be installed after the quartz crucible 28 is loaded with silicon chunks to be melted.

The normal operation of the CZ furnace with a ring ditched charge replenishment (CR) rod is shown sequentially in FIGS. 2A-2G. FIG. 2A shows the CZ furnace loaded with chunk polycrystalline silicon 26 in the quartz crucible 28 in the lower furnace chamber 14. A polycrystalline silicon rod 34 is attached to the seed holder 22 using a clamp or wire 36 that extends into a ring ditch 38 in the polycrystalline silicon rod 34 so that the rod hangs over the crucible. Both the upper and lower chambers 12, 14 are evacuated via a vacuum port 40 with the isolation valve 16 open.

The polycrystalline silicon chunk 26 is melted using the heater 24 to form a melt 42, that is a body of molten silicon. After the polycrystalline silicon chunk 26 is melted, the polycrystalline silicon rod 34 is lowered into the lower furnace chamber 14 so that it

FIGS. 3-7 show rod replenishment mechanisms (RRMs) that advantageously allow the melting of one or more polycrystalline rods and then the dipping of single crystal seed into the melt without intervening processing steps.

In the system of FIGS. 3A and 3B, an RRM includes a support body 160, a rod holder 152 extending from the support body 160, and a single crystal seed 178 connected to the rod holder. The RRM hangs from a lift mechanism 120 and supports a polycrystalline silicon rod 134 so that the rod hangs over a crucible. The illustrated support body 160 is a yoke that has two downwardly extending spaced-apart legs 174. The support body 160 is made of a material, such as quartz, molybdenum, tungsten or steel, that has sufficient strength to support the rod 134.

The RRM has a rod holder that is a hanger 152 extending from the support body 160 and connecting directly to the polycrystalline silicon rod 134. The rod holder 152 can be made out of quartz, silicon or some other non-contaminating material.

FIG. 3A and 3B show a keyhole system for attaching a CR rod to the rod holder 152. The polycrystalline silicon rod 134 has a surface that includes a top surface 172, a bottom surface (not shown), and a generally cylindrical side surface 135 that extends between the top and bottom surfaces. The rod 134 has a central axis A_1 that is surrounded by and extends generally parallel to the side surface 135. The top surface 172 is at the attached end of the rod when suspended. The bottom surface is at the free end of the rod, which free end is nearest the crucible when the rod is suspended.

As used herein, terms such as “cylindrical,” “circular,” and “spherical” should be taken in their broad senses. Although the term “circular” may be used herein, a typical polycrystalline silicon CR rod, as viewed from an end, is not perfectly circular, but is instead slightly elliptical in cross-section due to the ways in which such rods are grown.